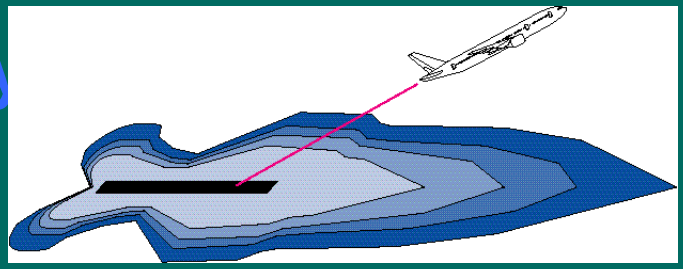
Advanced Subsonic Technology Noise Reduction



Presented at

Environmental Compatibility Assessment

Workshop III

William L. Willshire, Jr.

Monterey, California

July 7, 1998

Noise Reduction

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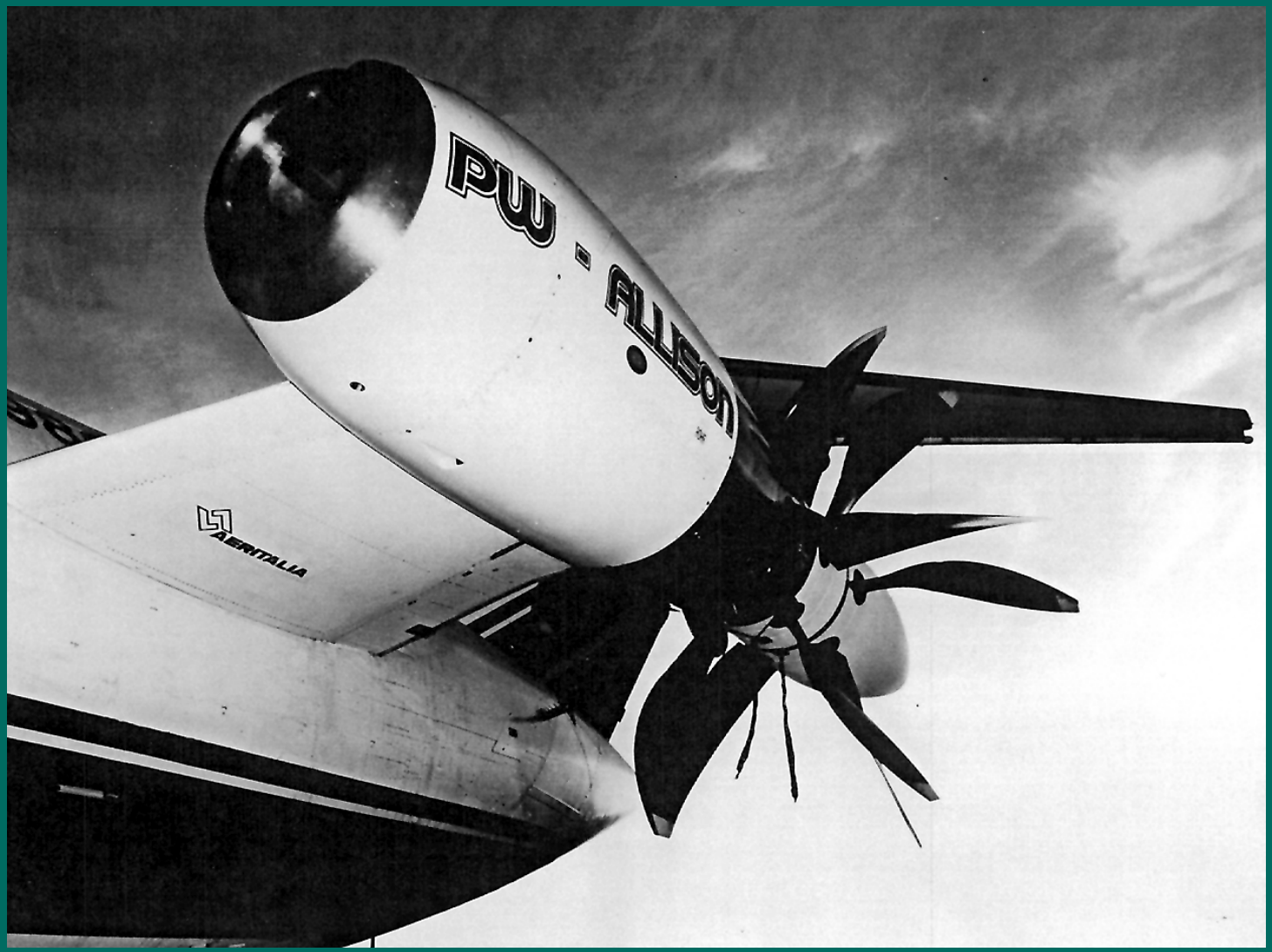
Early Advanced Configuration

Noise Reduction

Advanced Subsonic Technology

Recent Advanced Configuration



Noise Reduction

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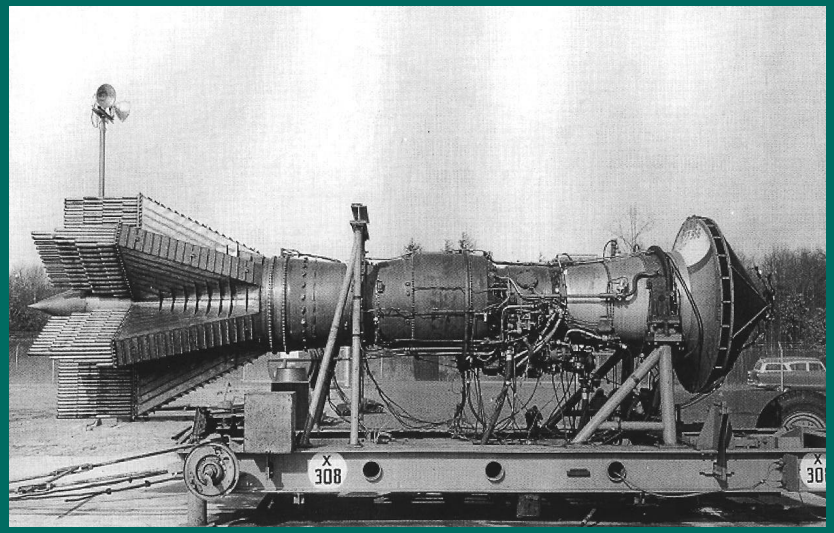
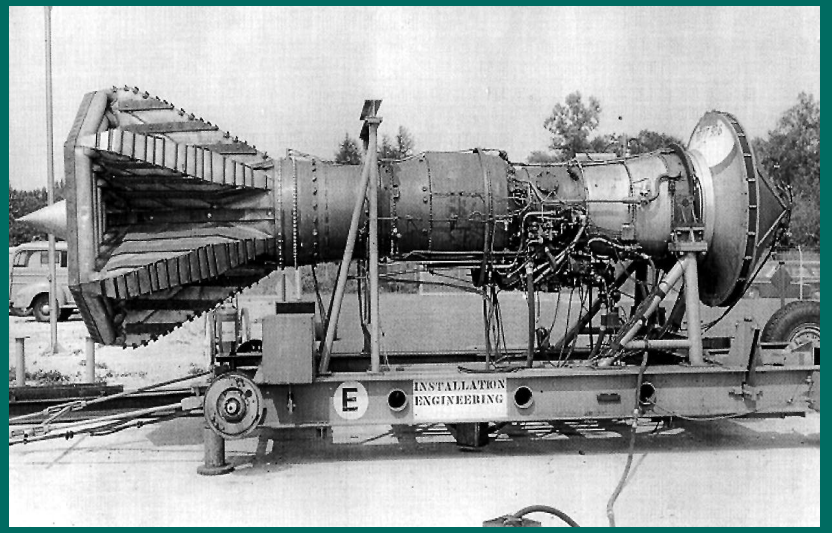
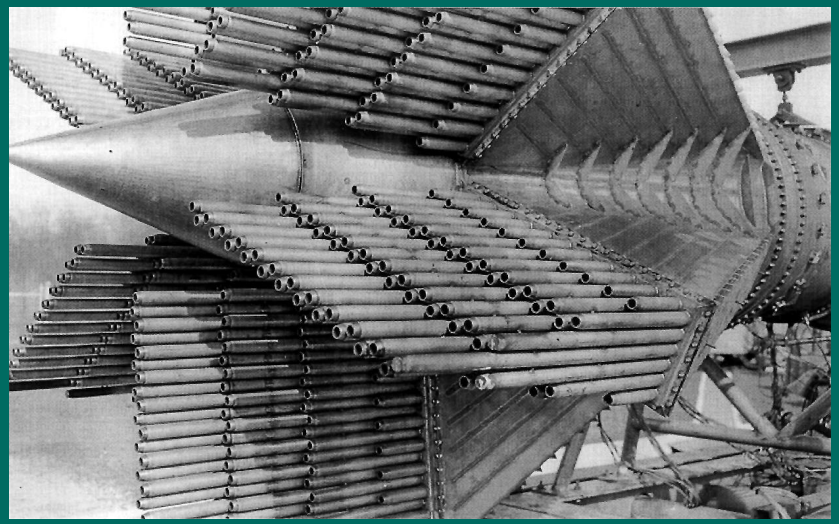
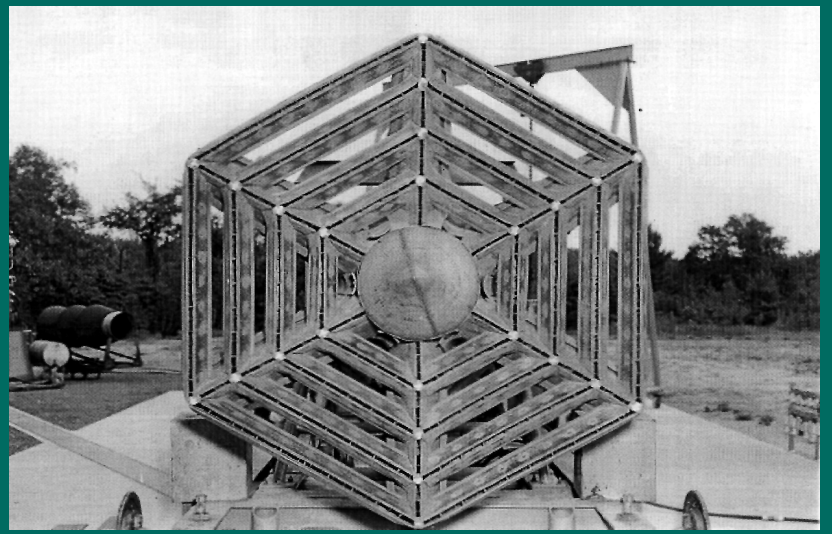
Desperation Can Lead to Innovation









Noise Reduction

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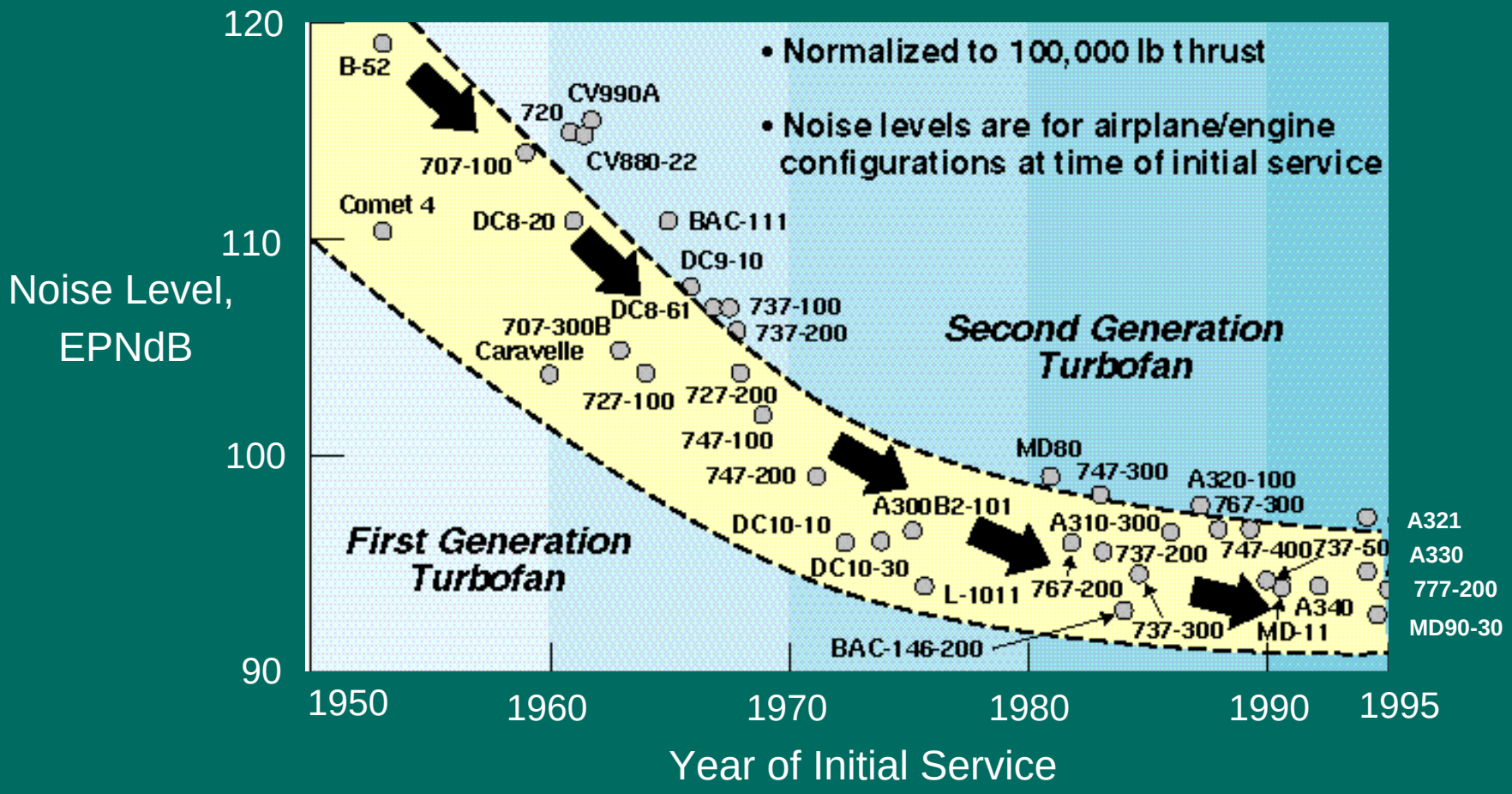
PROGRESS IN NOISE REDUCTION



- **Without new noise reduction technology, increasing demand coupled with increasing population will result in increased community noise impact.**

Noise Reduction

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BACKGROUND

9/90	FAA Research, Engineering, and Development Advisory Committee formed the Aircraft Noise Abatement Working Group
11/91	Aircraft Noise Abatement Working Group Report highlighted the need for a national noise reduction technology development program to meet future demands to avoid constraints
11/92	Airport and Airway Safety, Capacity, Noise Improvement, and Intermodal Transportation Act mandated that NASA and the FAA jointly conduct a subsonic noise reduction research program
11/92	Beginning of Joint FAA/NASA Subsonic Noise Reduction Program
10/93	Beginning of NASA Advanced Subsonic Technology Noise Reduction Program

Noise Reduction

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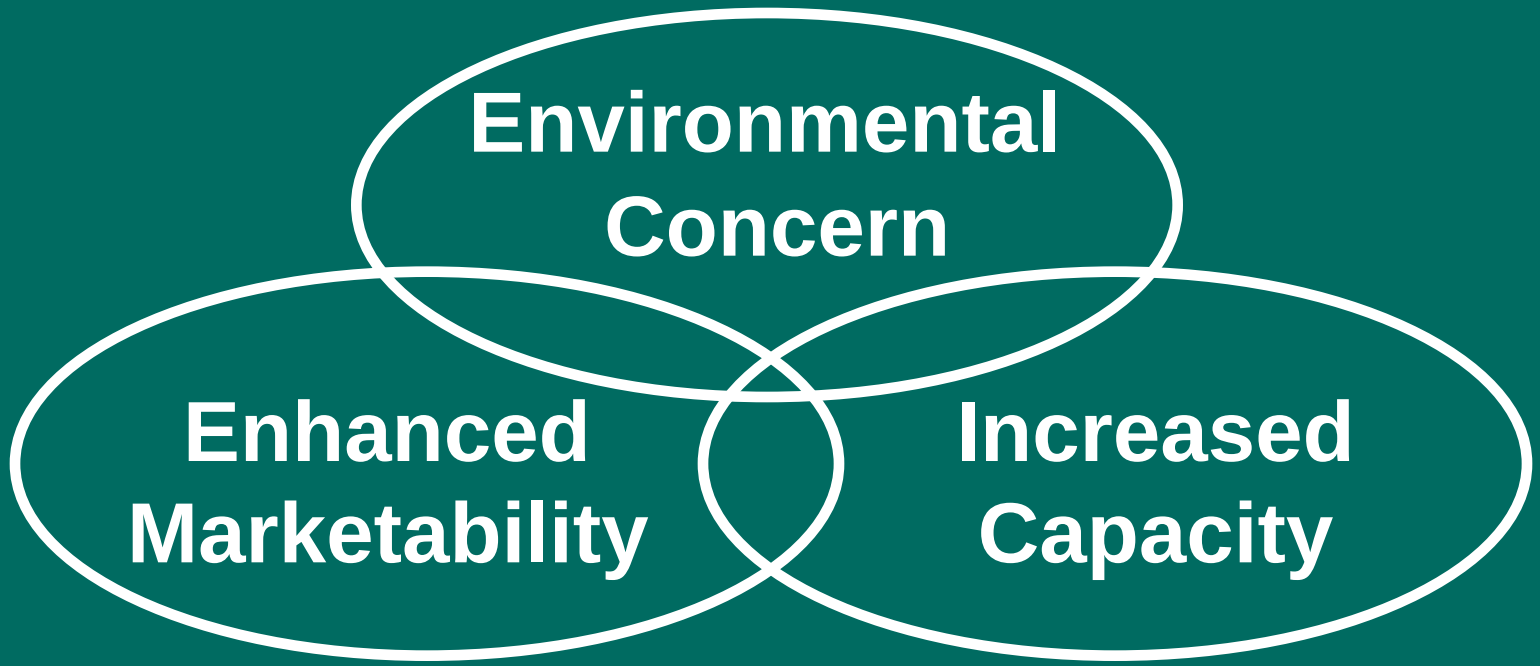
PROGRAM DRIVERS



Noise Reduction

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GOALS AND OBJECTIVES

Goal:

Provide Technology Readiness to Achieve-

- **Compliance with National/International Environmental Requirements**
- **Unrestrained Capacity**
- **Enhanced Marketability**

Objective:

- **10 dB Community Noise Impact Reduction Relative to 1992 Production Technology**

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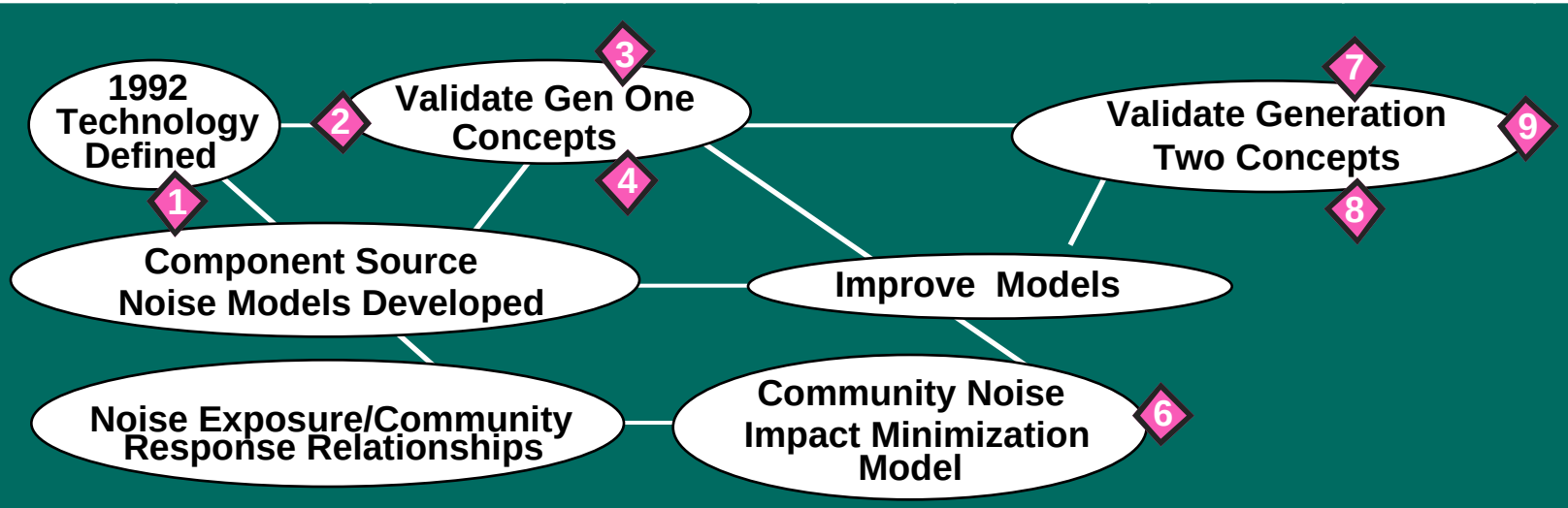
LEVEL I ROADMAP AND MILESTONES

FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	TOTAL
24.5	28.6	30.6	31.8	30.1	22.0	9.5	10.0	187.1

M $



1. First integrated fan noise source and propagation prediction code
2. Adaptive and active noise control duct treatment verified on low speed fan
3. Concepts validated for 3 dB jet noise for 1.5-6 BPR engines and 3 dB fan noise reduction*
4. Concepts validated to improve nacelle duct treatment effectiveness by 25%*
6. Validated prediction and minimization methodology for community noise impact
7. Demonstrated 6 dB interior noise reduction*
8. Validated technology to reduce aircraft noise by 10 dB*
9. Large-scale component validation of noise reduction technology

*Relative to 1992 production technology

Noise Reduction

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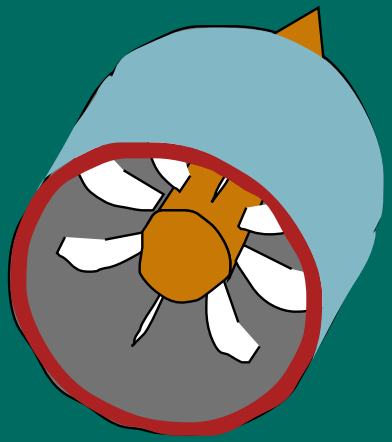
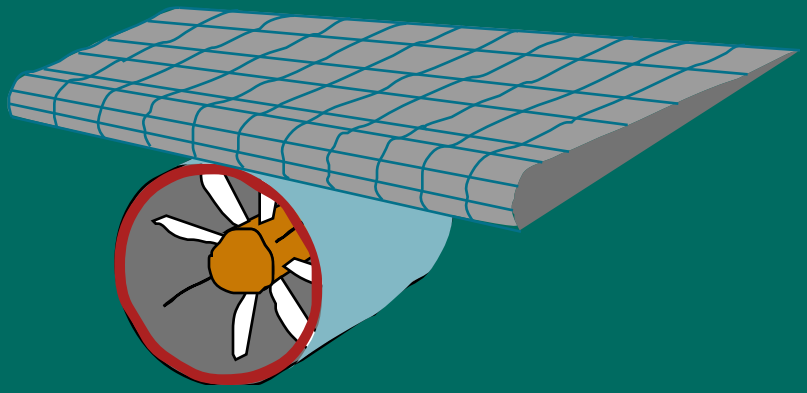
Subelements

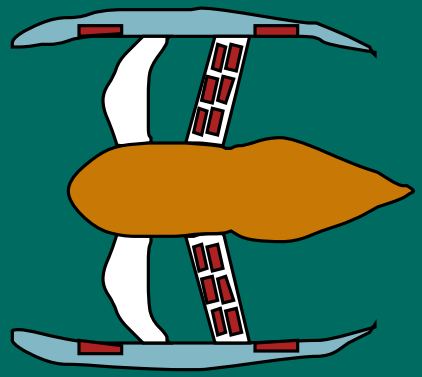
Engine Noise Reduction



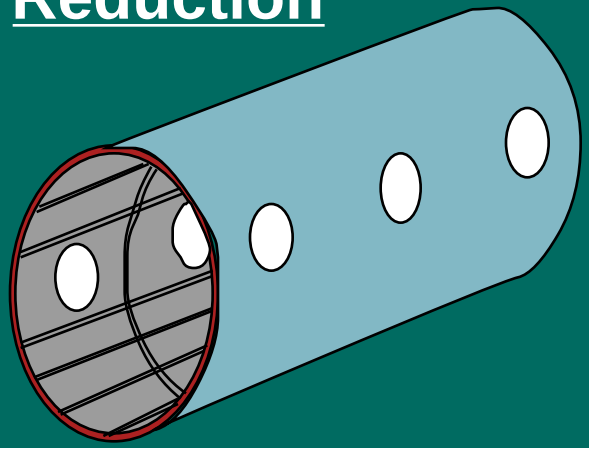
Airframe Noise Reduction



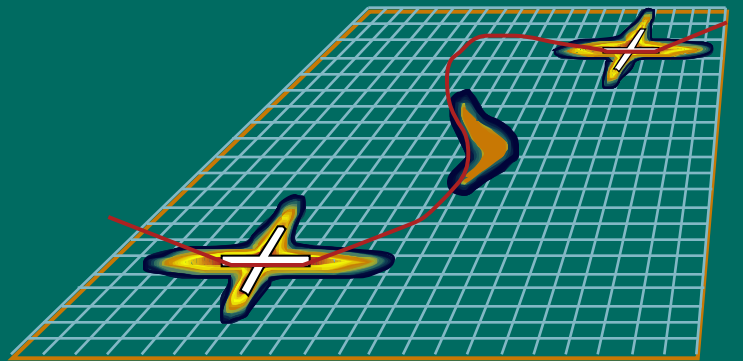
Nacelle Aeroacoustics



Interior Noise Reduction



Community Noise Impact



Noise Reduction

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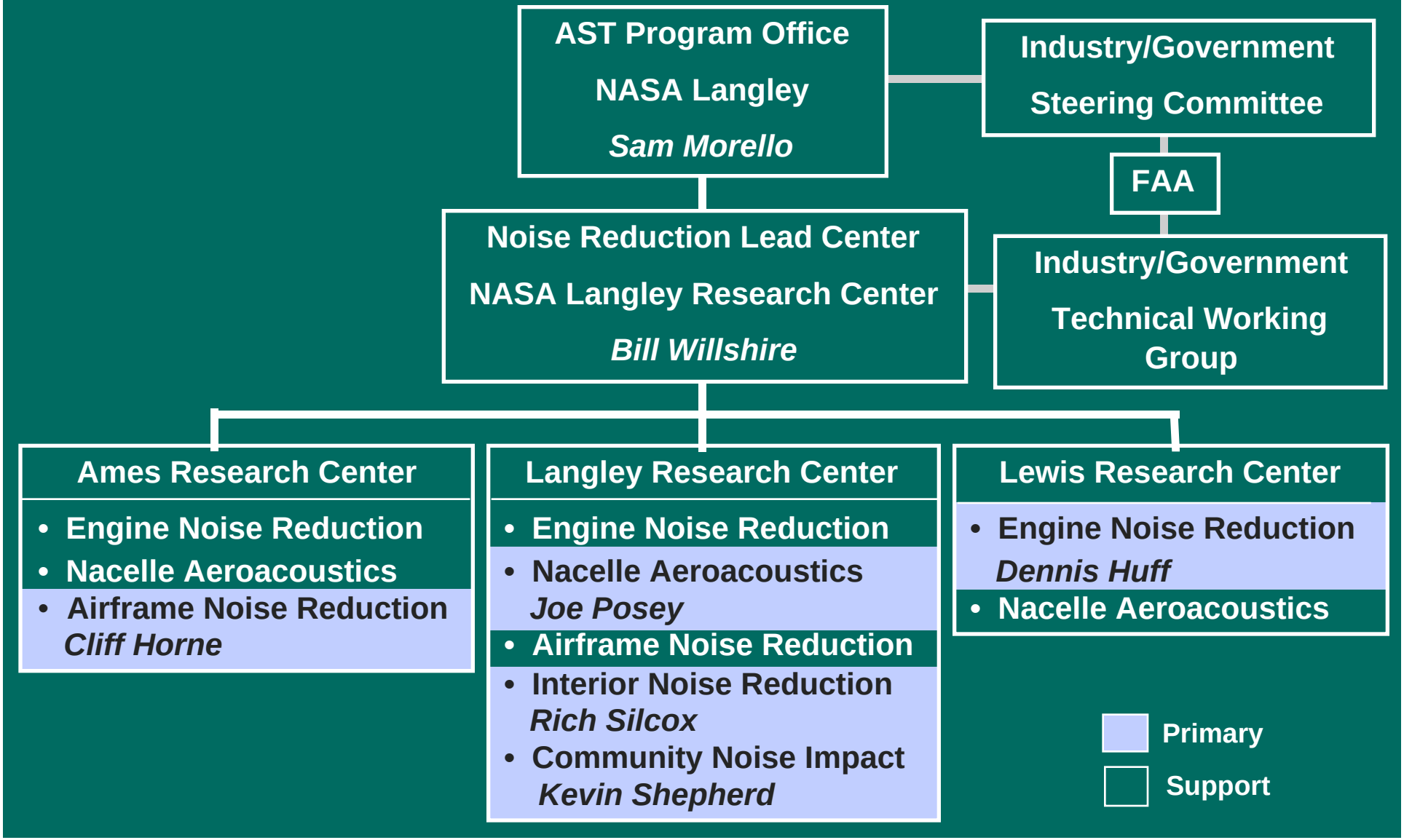
AST MANAGEMENT STRUCTURE



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INDUSTRY TEAMS/STEERING COMMITTEES

Steering Committee

(10th meeting 3/26/98)

AlliedSignal... Weir
Allison..... Dalton
ALPA..... Davis
Boeing Sea... Craig
Boeing LB.... Joshi
DFW..... Robertson/Linn

Delta..... Brown
Gulf. Aero.. Hilton
GE..... Gliebe
N.O.I.S.E.... Kane
P&W..... Wagner

Ex-Officio:
NASA... Morello
FAA..... Erickson

Technical Working Group

(14th meeting 3/24-25/98)

Industry

AlliedSignal... Weir
Allison..... Dalton
Boeing Sea... Reed
Boeing LB..... Joshi
Cessna..... Howes
GE..... Gliebe

Lockheed... Reddy
Northrop.... Parente
P&W..... Mathews
Rohr..... Yu
Sikorsky.... Jacobs
Williams.....Defever

NASA

Horne
Huff
Posey
Shepherd
Silcox
Stephens
Willshire

FAA

Skalecky

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Subelement Success Requirements

Subelement	Objective	Minimum Success
Engine Noise Reduction	6 dB Engine Noise Reduction*	4 dB
Nacelle Aeroacoustics	50% Liner Efficiency Improvement *	35%
Airframe Noise Reduction	4 dB Airframe Noise Reduction *	2 dB
Interior Noise Reduction	6 dB Noise Reduction *	4 dB
Community Noise Impact	Community Noise Impact Minimization Model (2-3 equivalent dB reduction through advanced operations)	Same
Noise Reduction Program	10 dB Community Noise Impact Reduction*	7 dB

*Relative to 1992 production technology

Noise Reduction

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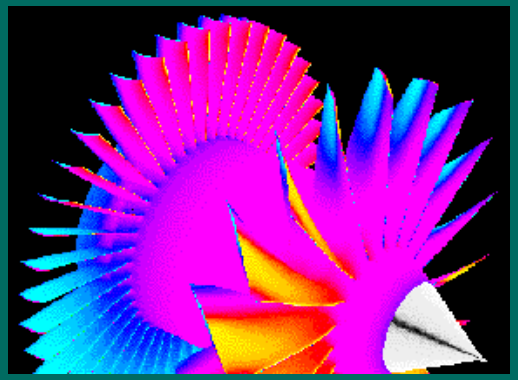
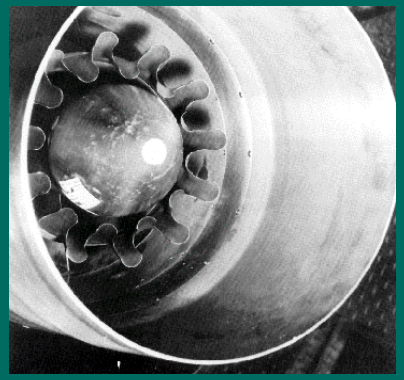
Interim Level I Milestones

- 3 dB fan noise reduction



- Minimum fan tone stator design

- 3 dB jet noise reduction



- Improved mixer design tool

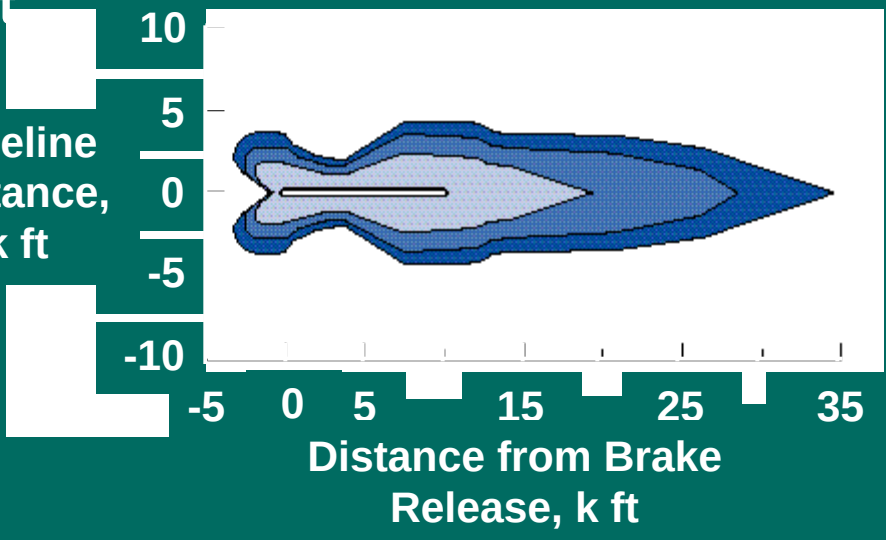
- 25% liner improvement

- Improved design process

Benefit

Small Twin 80 EPNdB Takeoff Noise Contours

	Contour Area, SqMi	Percent Reduction, %
Baseline	7.9	-
Interim (1997) Goals	5.4	32
Final (2001) Goals	2.5	68



Noise Reduction

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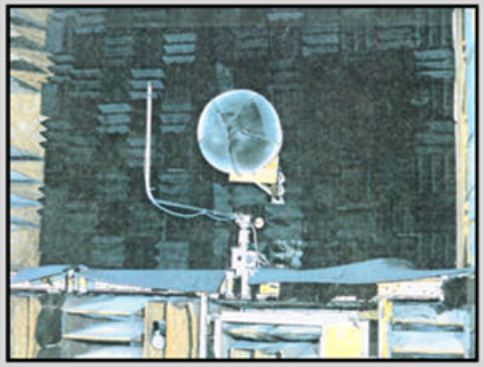
Fan Broadband Noise Test

Noise Reduction

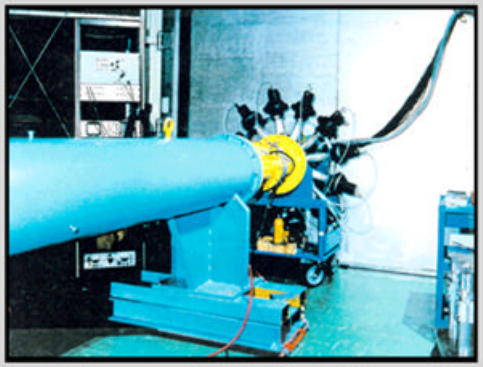
Advanced Subsonic Technology

Active Fan Noise Control with In-duct Error Microphone

Ducted Fan System

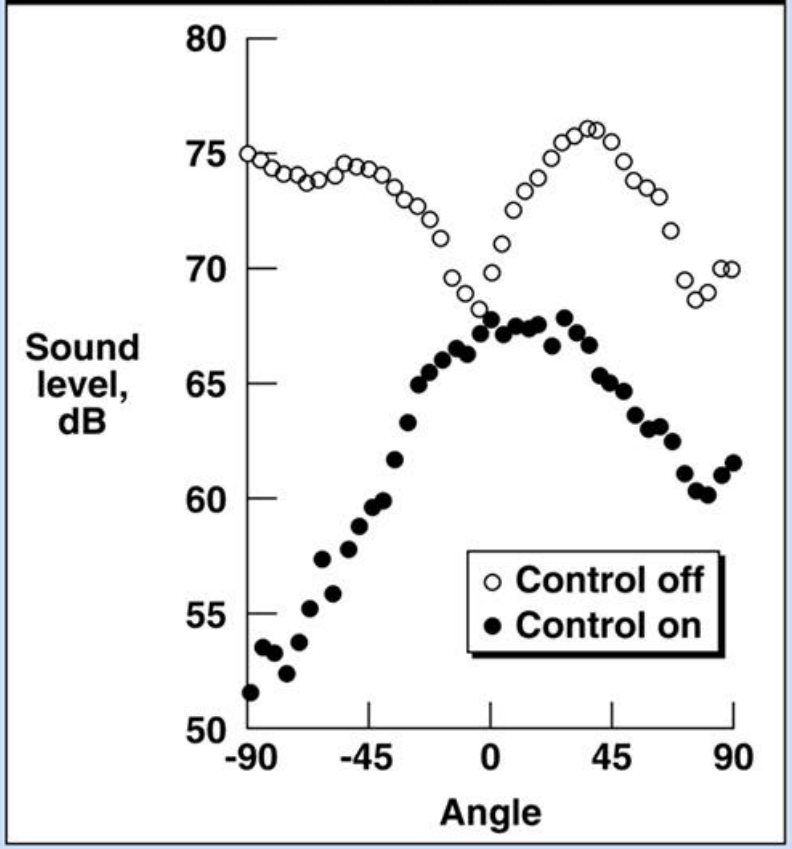


View from Inside Chamber



View from Outside Chamber

Far Field Directivity of the BPF Tone, Fan Speed = 2800 rpm, M = 1 Mode Generated



Noise Reduction

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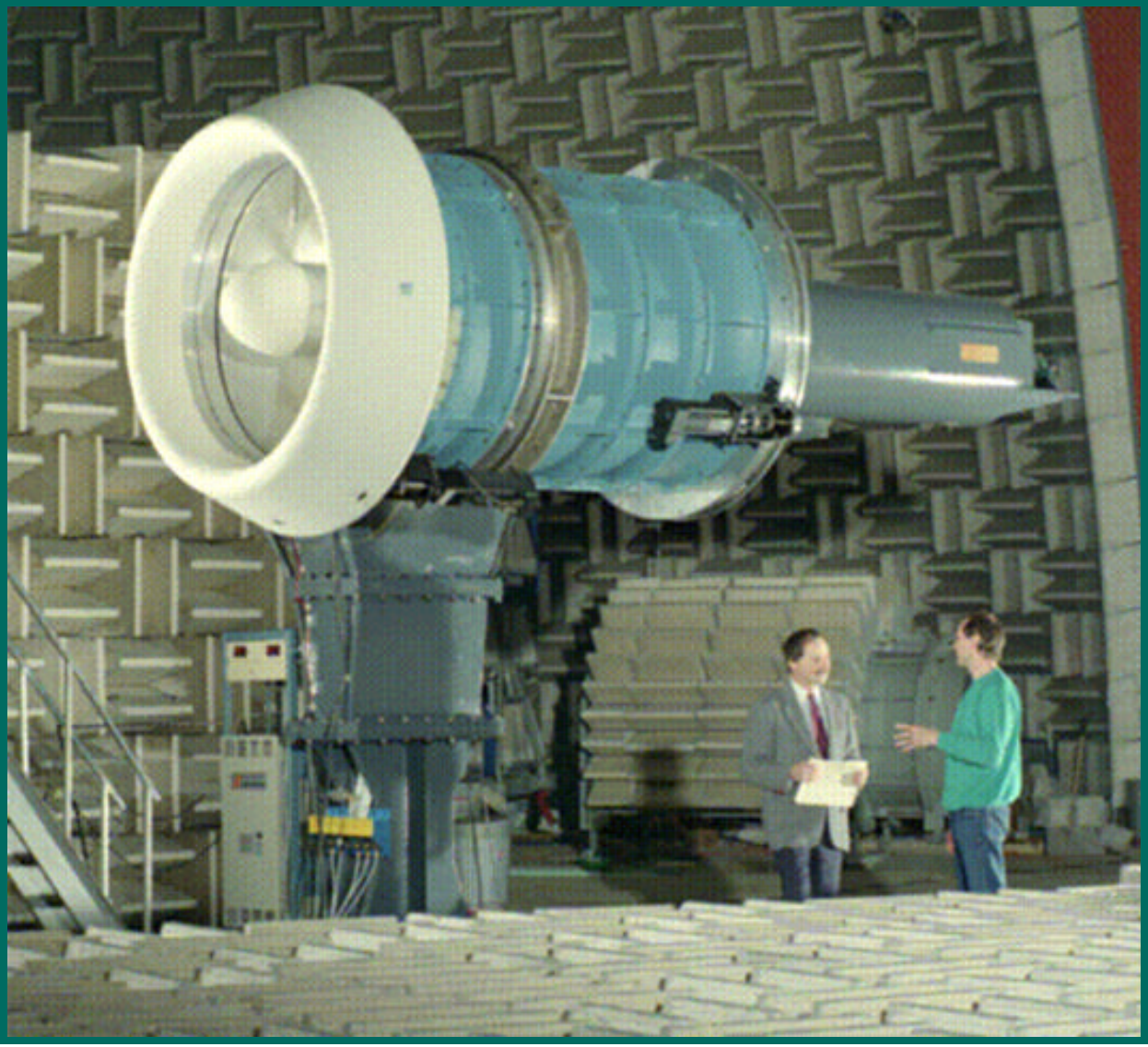
Active Fan Noise Control Test Rig



Noise Reduction

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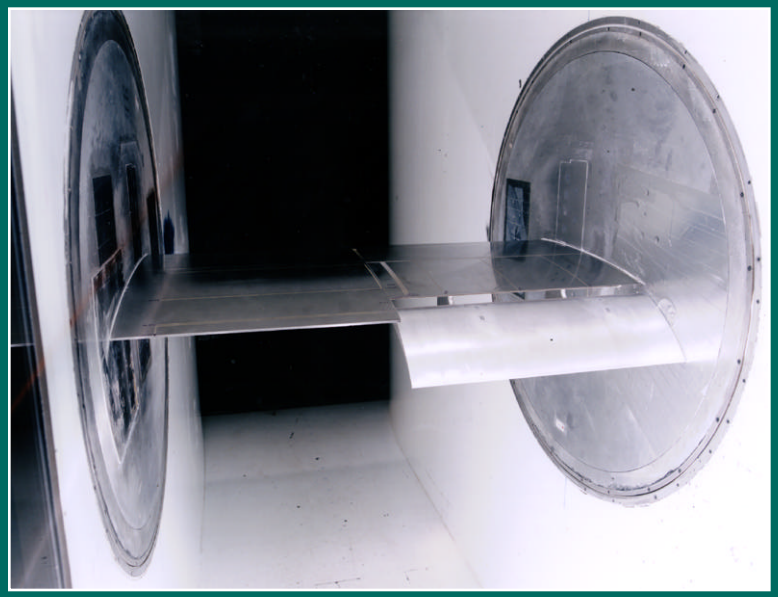
NR97-LTPT

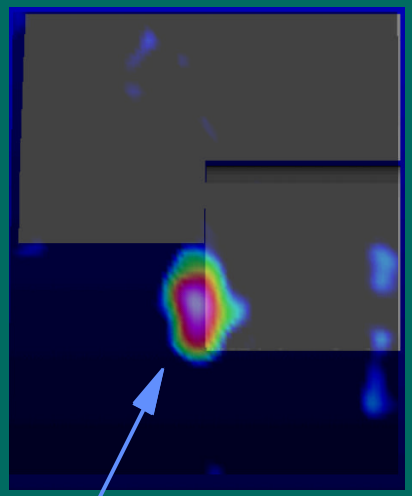
Low Turbulence Pressure Tunnel High Lift Airframe Noise Experiment

High-Lift Model

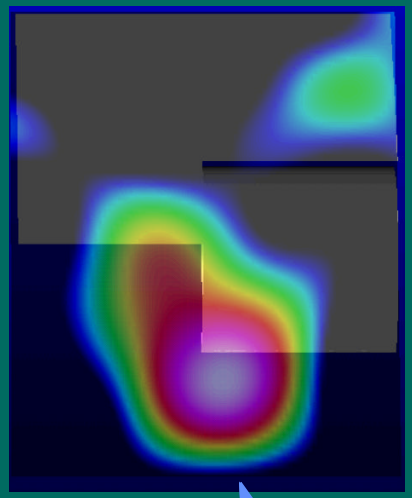


Microphone Array Results

f = 16.30 kHz

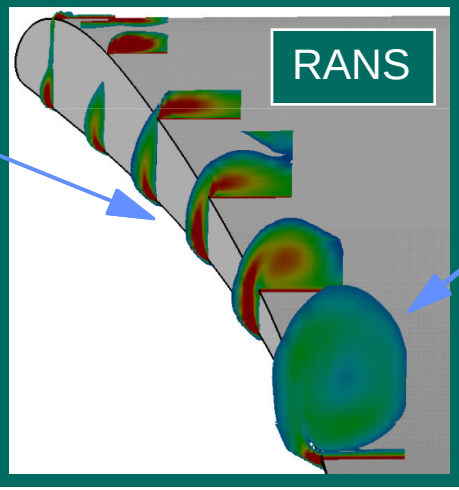


f = 4.10 kHz



Flap Edge

Trailing Edge



- **Full scale R_C number**
- **Acoustic measurements in hard-walled tunnel**
- **Two acoustic source regions**

Noise Reduction

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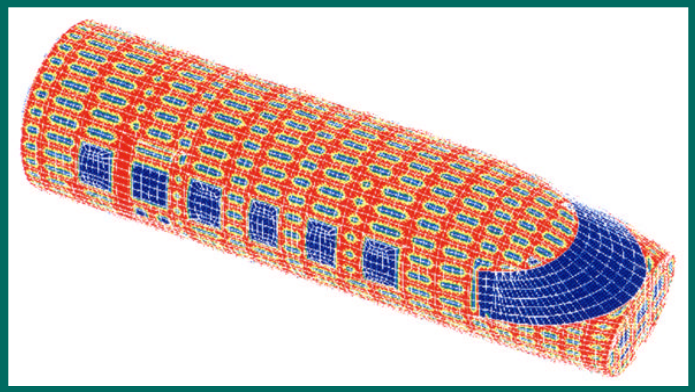
NR97-MDOp

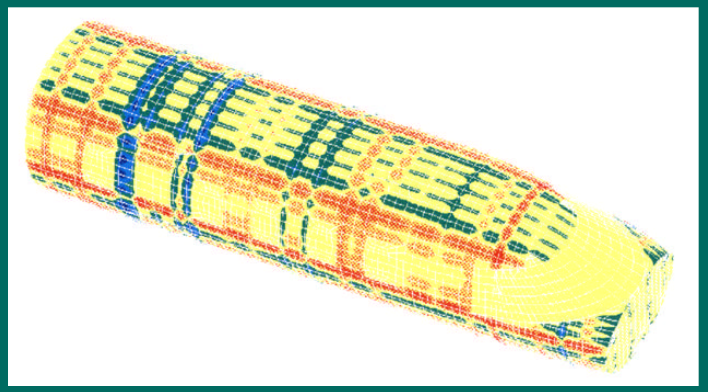
Structural Acoustic Optimization

Baseline



Red indicates stiffener (ring frames and longerons) locations

After Optimization



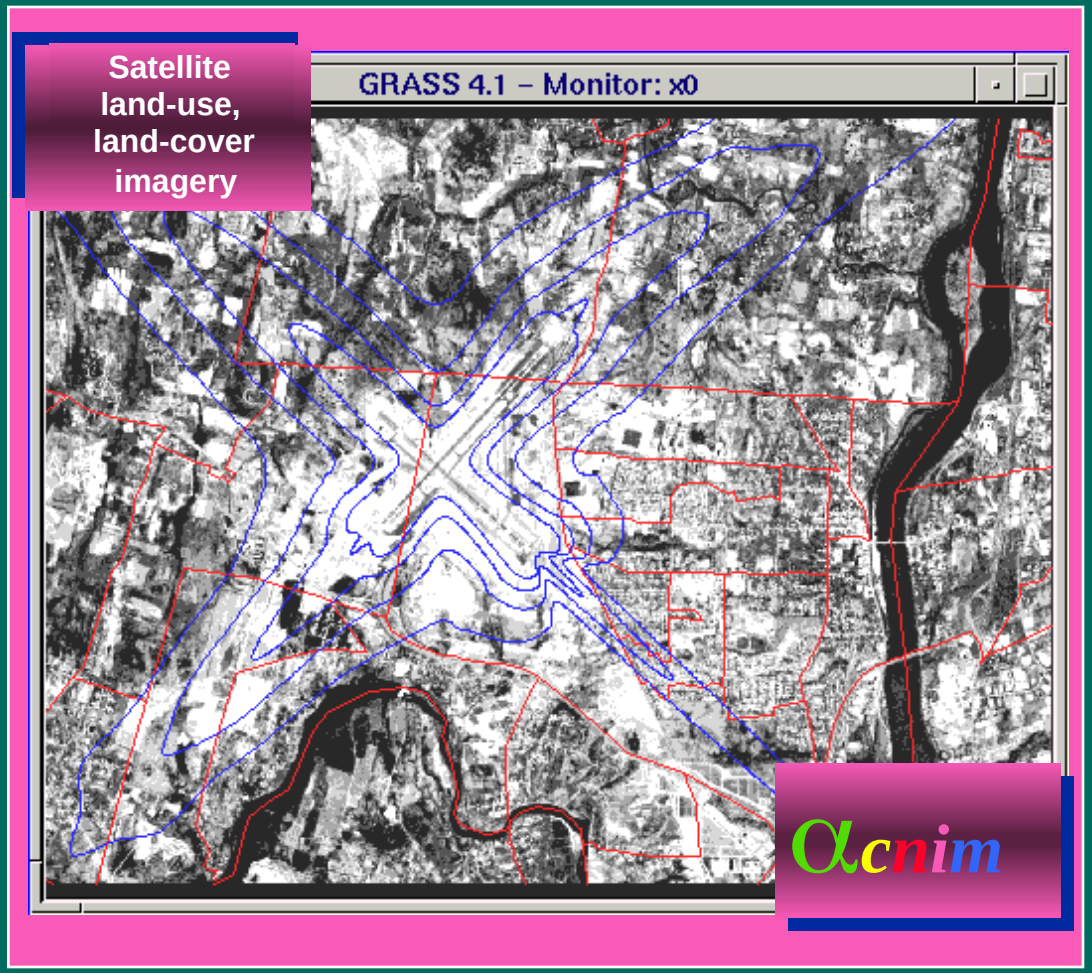
Color indicates stiffener sizing scale factor

- Cessna Citation III
- Multifrequency (190-200 Hz)
- Pressurized fuselage
- Fuselage weight held constant
- Maximum stress constrained
- Design variable bounds (.8 to 1.2)
- 6.3 dB interior broadband noise reduction

Noise Reduction

Advanced Subsonic Technology

Development of Airport Community Noise Impact Model (ACNIM)



Noise Reduction

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Advanced Noise Reduction Technologies

- Computational Advances
  - Computational aeroacoustics
  - Computational fluid dynamics
  - Direct numerical simulation
- Multidisciplinary Optimization
  - Engine fan design for acoustics and performance
  - Interior noise structural/acoustics optimization
- Active Noise Control
  - Engine noise
  - Interior noise
  - Transmission/engine vibration
- Measurement Technology
  - Microphone arrays

Noise Reduction

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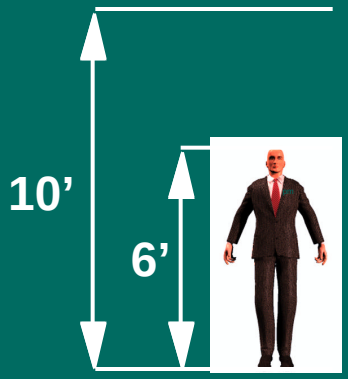
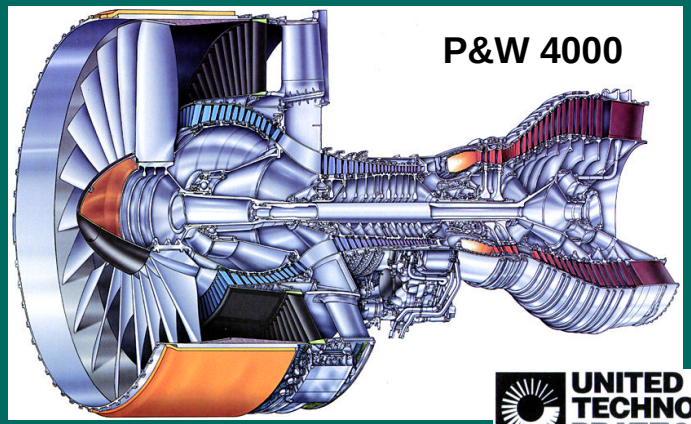
Pratt & Whitney 4098 Static Test





BOEING BFGoodrich Aerospace

UNITED TECHNOLOGIES PRATT & WHITNEY

- Scarf inlet designed and fabricated
- Advanced fan/stator geometries
- Advanced jet noise suppression
- First phase of test scheduled for August 1998

Noise Reduction

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40’ x 80’ Star Model Test

- 26% 777 semi-span model
- Advanced flap, slat, and gear airframe noise reduction concepts
- Microphone array
- Test scheduled for November 1999

Noise Reduction

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SUMMARY

- **A broad, multi-year technology development program scheduled for completion in 2001.**
- **Noise reduction is enabling technology for enhanced marketability, capacity, and environmental requirements.**
- **Technical program is result of an extensive NASA inter-center, FAA, and industry partnership.**
- **Status:**
  - **Goals ambitious**
  - **Potential benefits large**
  - **Interim objectives reached**

BACK-UP CHARTS

Noise Reduction

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DEFINITION OF 1992 TECHNOLOGY

- **Boeing FY94/FY95 task to establish noise levels representative of 1992 production technology.**
- **Task broken into four classes of airplanes: small twin, medium twin, large quad, and business jet (this work subcontracted to Allied Signal in FY95).**
- **Established one-third octave band component noise levels for each generic airplane class based on certification data base.**
- **Progress toward goals assessed based on component noise prediction relative to 1992 definition.**

Noise Reduction

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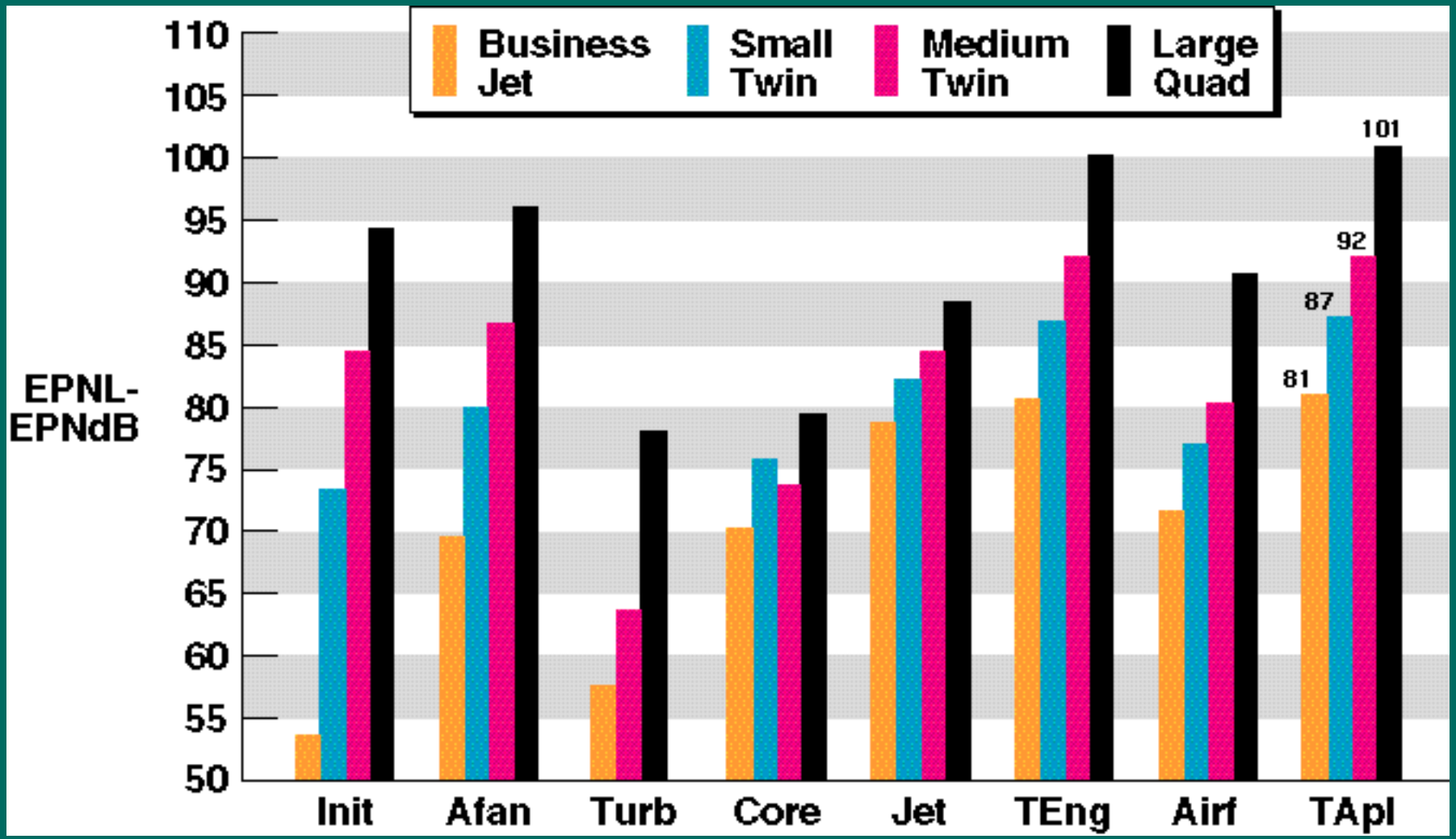
1992 TECHNOLOGY AIRCRAFT NOISE LEVELS

FAR 36 Stage 3 Takeoff with Cutback



Noise Reduction

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NR97-SoundQu

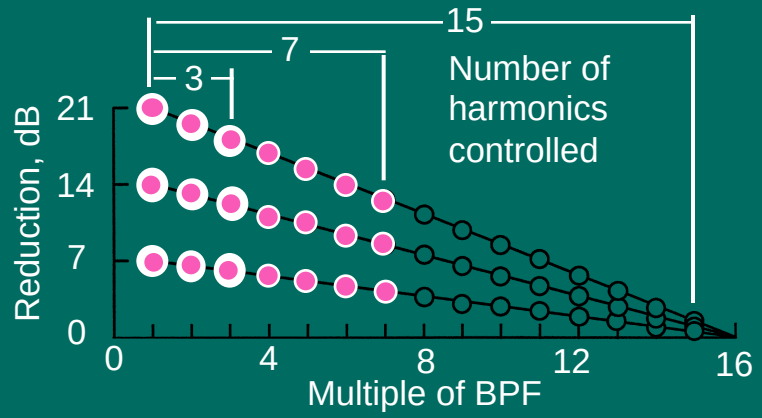
Passenger Response to Interior Noise

- **Aircraft Interior Acoustic Simulator developed**
- **Anticipated effectiveness of active noise control of propeller tones determined in Sound Quality tests**

Active Noise Control Sound Quality Investigation

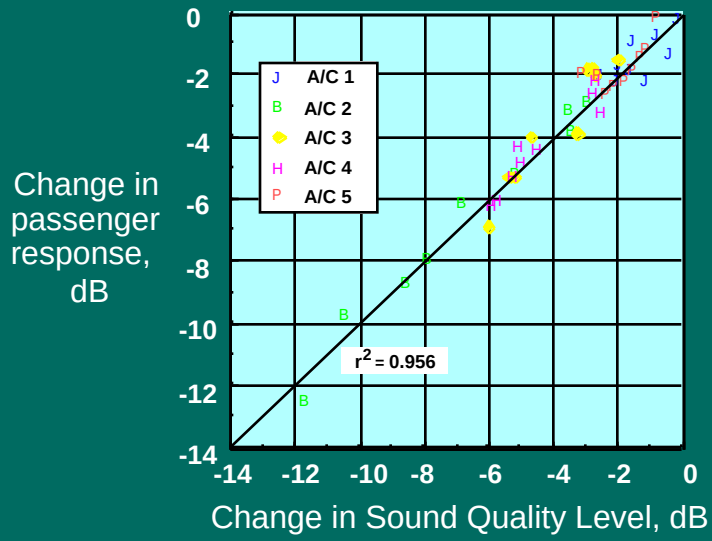
- 40 subjects
- 5 propeller aircraft
- 3 degrees of ANC complexity
- 3 levels of ANC effectiveness

ANC Tone Reduction Complexity & Effectiveness



Aircraft Interior Acoustic Simulator

Sound Quality Test Results



Noise Reduction

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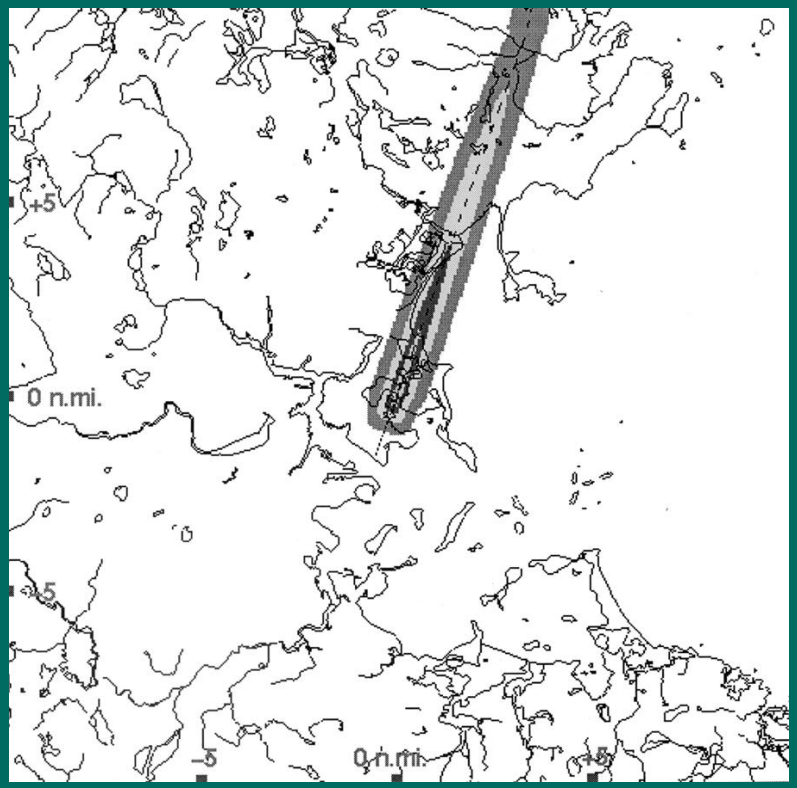
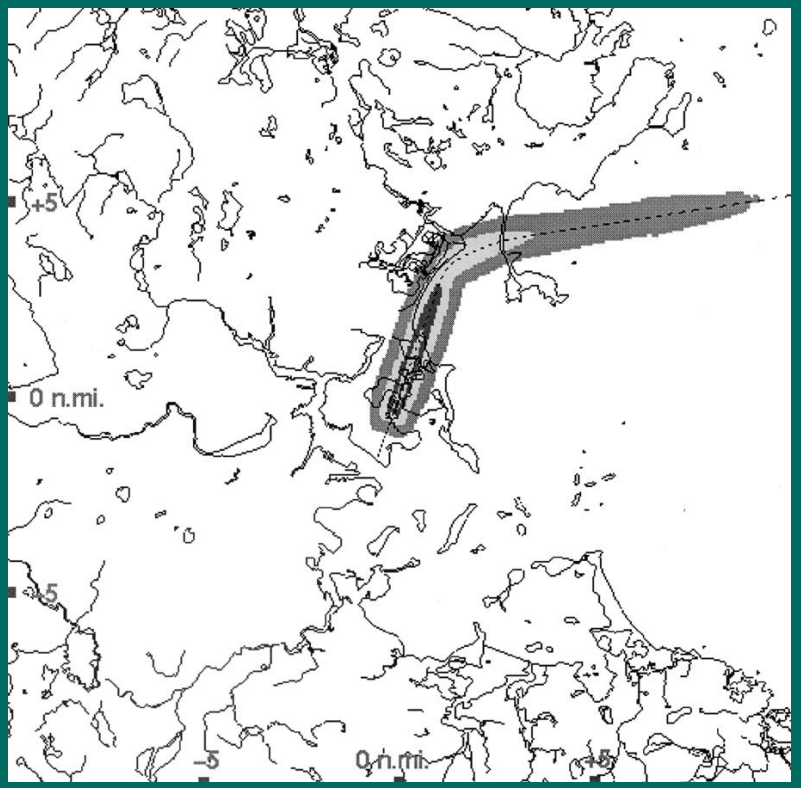
Noise abatement Procedures Enabled by Advanced Flight Guidance Technology

ILS Approach



Curved Approach



Noise Reduction

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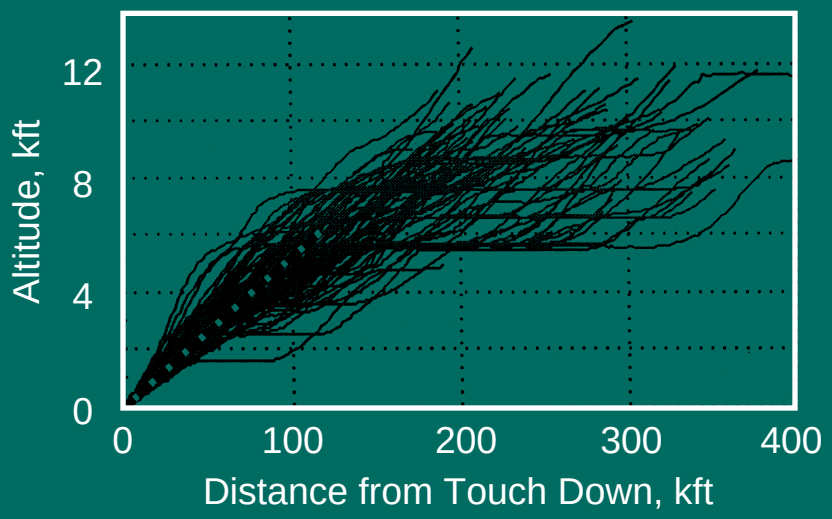
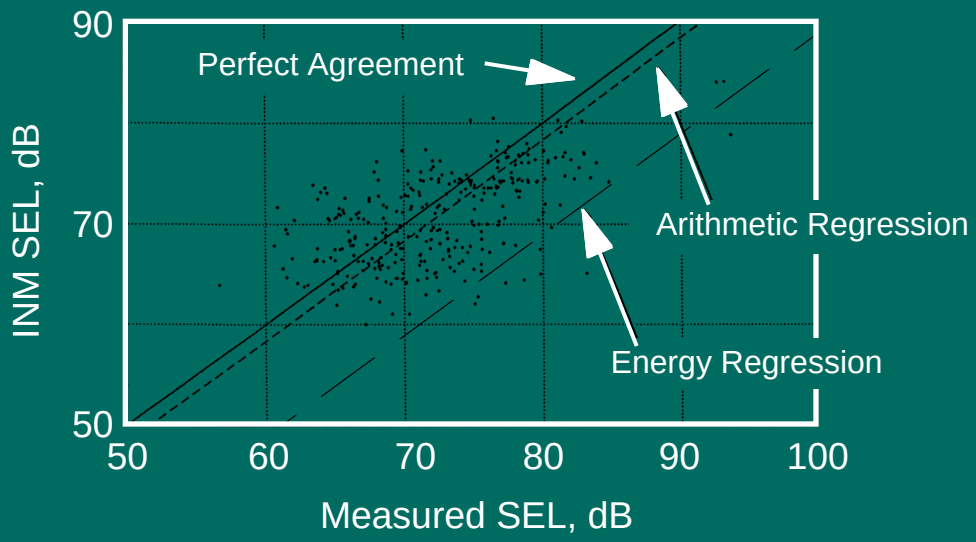
NR97-INM

Validation of Integrated Noise Model (INM)

727 Approaches to DIA Over 24 hr Period



Predicted Versus Measured SEL



- Variability in flight paths
- INM slightly underpredicts on average on dB basis
- Supports discussion of single event metrics to predict overall community noise impact
- Opportunity with advanced flight management technology to greatly reduce community noise impact

Noise Reduction

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Lessons Learned from Program Manager's Perspective

- Involve/partner with industry early { SC/TWG working well}
- Involve/partner with FAA early { SC/TWG working well}
- Establish program and implement as national team
- Plans should include early successes
- Perform system level studies to identify highest payoff technical areas
- Define and get into place necessary contract vehicles early
- Define quantifiable baseline
- Level III technical leaders manage across centers
  - Define program assessment process
  - Maintain element level reserves
  - Streamline reporting/review process
  - Establish technology transfer/protection policy early
  - Define program metrics and roadmaps early
  - Plans should include milestones which support upper level milestones
  - Set up WBS to track investment per Level I milestone

Noise Reduction

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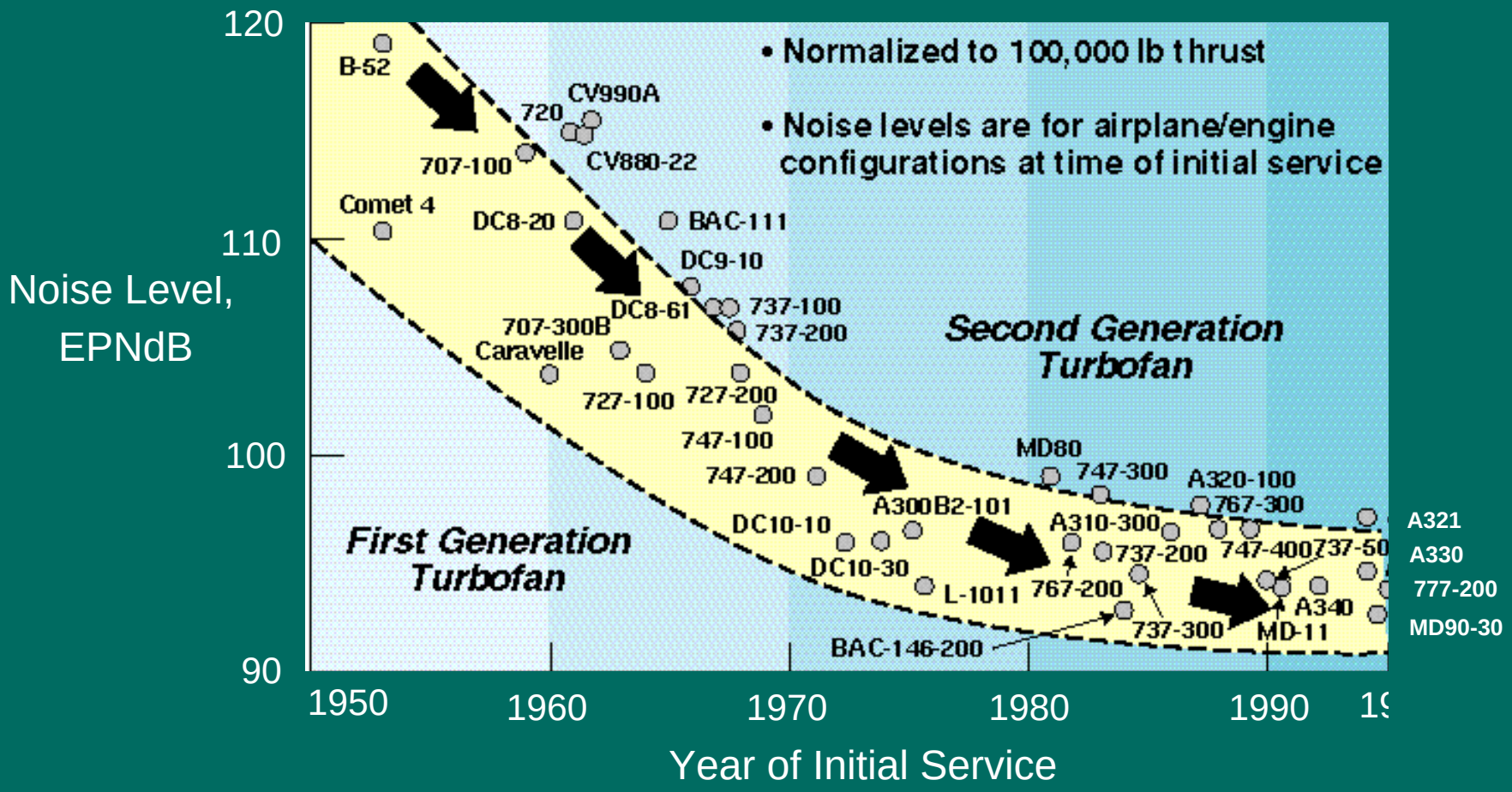
PROGRESS IN NOISE REDUCTION



- **Without new noise reduction technology, increasing demand coupled with increasing population will result in increased community noise impact.**